

CLAIMS

What is claimed is:

1. A method for noninvasive determination of magnetic susceptibility variation in a patient by measuring magnetic susceptibilities of selected tissue of the patient, the method comprising:

providing an instrument which includes at least one magnetic sensor, an applied field coil and a current source connected to the applied field coil and means for processing sensed signals from the at least one magnetic sensor;

positioning on the patient a flexible bag substantially filled with deformable material having a magnetic susceptibility substantially similar to that of body tissue, said bag being attached to a substantially rigid barrier, the barrier being spaced from the patient by the liquid-filled bag;

positioning the instrument external to the patient in proximity to the tissue of interest and adjacent the barrier;

supplying the applied field coil with current thereby applying a magnetic field to the tissue of interest;

sensing a response from the tissue of interest with the instrument; and

outputting data corresponding to the magnetic susceptibility variation in the tissue.

2. The method recited in claim 1, wherein an alternating current is supplied to the applied field coil.

3. The method recited in claim 1, wherein the method further comprises providing the instrument with displacement means for displacing the magnetic sensor and the applied field coil simultaneously thereby compensating for noise introduced to the sensed signals.

4. The method recited in claim 3, wherein the displacement means operates between about one to six inches.

5. The method recited in claim 3, wherein the displacement means operates between
2 about 0.5 to 10.0 hertz.

6. The method recited in claim 1, wherein the outputting of data corresponding to
2 the magnetic susceptibility variation in the human body comprises concentrations of
paramagnetic material in the tissue of interest.

7. The method recited in claim 6, wherein the paramagnetic material is iron and the
2 tissue of interest is a liver.

8. The method recited in claim 7, wherein the outputting of data corresponds to
2 concentrations of iron in the liver and the resolution of the measurements corresponds to about
30 micrograms per milliliter.

9. The method recited in claim 1, wherein the positioning step functionally replaces
2 the irregular or variable shape of the patient's body with a volume of material similar in magnetic
susceptibility to body tissue, whose surface has a constant shape defined by the rigid barrier;

10. An apparatus for noninvasively measuring magnetic susceptibility variations in
2 the body tissue of a patient to determine a compositional state in the body, the apparatus
comprising:

4 a detector assembly that includes:

6 at least one magnetic sensor and an applied field coil for generating a magnetic
field;

8 a current signal generating source which connects to said applied field coil; and

means for processing signals from said at least one magnetic sensor of observed
magnetic susceptibility variations in body tissue;

10 a non-conductive, non-magnetic, substantially rigid barrier;

a flexible membrane sealed to said barrier to form a container therewith, there being a
12 deformable material within and occupying most of the volume within said container, said
material having a magnetic susceptibility substantially equivalent to that of the body tissue, said
14 container being shaped and configured to fill in substantially all gaps between said barrier and
the patient's body; and
16 means for outputting data from said detector assembly corresponding to a compositional
state in the body.

11. The apparatus recited in claim 10, wherein the current signal generating source
2 provides alternating current (AC).

12. The apparatus recited in claim 10, wherein the means for processing signals from
2 the at least one magnetic sensor comprises a processor for analyzing the signals obtained from
the magnetic sensor.

13. The apparatus recited in claim 10, wherein the means for processing signals
2 further comprises outputting means for displaying paramagnetic material concentration.

14. The apparatus recited in claim 13, wherein the paramagnetic material is iron.

15. The apparatus recited in claim 10, wherein the applied field coil is designed to
2 create a first zone of a finite magnetic field within a selected region of the body, and a second
zone of substantially zero magnetic field outside the selected region; and

4 said at least one magnetic sensor is positioned within said second zone of substantially
zero magnetic field.

16. The apparatus recited in claim 10, wherein said at least one magnetic sensor
2 attaches to a central region relative to the applied field coil.

17. The apparatus recited in claim 10, wherein said at least one magnetic sensor
2 attaches to a central region relative to said applied field coil and said applied field coil is attached
to a planar substrate.

18. The apparatus recited in claim 15, wherein said applied field coil comprises two
2 parallel flat coils and a connecting circuit between said two parallel coils causing current to flow
in identical directions at corresponding locations in said two flat coils, thereby simulating
4 parallel uniform sheets of current.

19. The apparatus recited in claim 15, wherein said excitation field coil comprises at
2 least two concentric coils and a connecting circuit between said at least two concentric coils
causing current to flow in opposite directions, thereby canceling the effects of a magnetic field
4 caused by current flowing through said applied field coil at a central region of said at least two
concentric coils.

20. The apparatus recited in claim 15, wherein said detector assembly is multiple
2 stacked applied field coils.

21. The apparatus recited in claim 10, wherein said at least one magnetic sensor is a
2 magnetoresistive sensor.

22. The apparatus recited in claim 10, wherein said at least one magnetic sensor is a
2 fluxgate sensor.

23. The apparatus recited in claim 10, wherein said at least one magnetic sensor is a
2 magnetoinductive sensor.

24. The apparatus recited in claim 21, wherein said at least one magnetoresistive
2 sensor is part of a Wheatstone bridge sensing circuit.

25 The apparatus recited in claim 24, and further including magnetic sensor
2 compensating electronics and a feedback coil disposed about said magnetoresistive sensor for
locking an optimum operating point by applying a compensating electrical current from
4 compensating electronics to said feedback coil thereby maintaining constant measurement
sensitivity of the apparatus.

26. The apparatus recited in claim 10, wherein said detector assembly further
2 comprises a means for oscillating said detector assembly.

27. The apparatus recited in claim 26, wherein said detector assembly is housed in a
2 housing structure for positioning said detector assembly in proximity to a surface of the human
body, and said means for oscillating said detector assembly comprises a motor with attached
4 drive members that move said detector assembly.

28. The apparatus recited in claim 19, wherein the larger of said concentric coils has a
2 diameter ranging between about 15 to about 50 centimeters.

29. The apparatus recited in claim 19, wherein there are at least three concentric coils,
2 the outermost coils include at least two coils which are alternatively switched with the current
source, whereby sufficient information can be derived independently as to the susceptibility of a
4 deep lying tissue area in the body compared to a corresponding surface tissue area.

30. The apparatus recited in claim 29, wherein the deep lying tissue area is the liver
2 and the overlying surface tissue area is abdominal tissue.

31. The apparatus recited in claim 10, wherein said detector assembly comprises an
2 applied field coil on a cylindrical coilform and sensor coils axially spaced from said field coil on
either side thereof.

32. The apparatus recited in claim 31, wherein said sensor coils are oppositely around
2 in a gradiometer configuration.

33. The apparatus recited in claim 31, wherein said coilform is formed of non-
2 magnetic, non-metallic material.

34. The apparatus recited in claim 10, wherein said deformable material is water.

35. The apparatus recited in claim 10, wherein said deformable material is a gel.

36. A magnetic susceptibility detector device comprising:
2 an applied field coil configured to connect to a current source, said field coil being
configured to create a first zone of a finite magnetic field within a selected region of an observed
4 specimen, and a second zone of substantially zero magnetic field outside said selected region,
said applied field coil having at least two concentric electric current carrying coils of conductor
6 material;
a sensing device comprising at least one magnetic sensor, said at least one sensor being
8 positioned within said second zone of substantially zero magnetic field;
a non-conductive, non-magnetic, substantially rigid barrier; and
10 a flexible membrane sealed to said barrier to form a container therewith, there being a
deformable material within and substantially filling said container, said material having a
12 magnetic susceptibility substantially equivalent to that of the body tissue, said container being
shaped and configured to fill in substantially all gaps between said barrier and the patient's body.

37. The device recited in claim 36, wherein said at least one magnetic sensor is a
2 magnetoresistive sensor.

38. The device recited in claim 36, wherein said at least one magnetic sensor is a
2 fluxgate sensor.

39. The device recited in claim 36, wherein said at least one magnetic sensor is a
2 magnetoinductive sensor.

40. The device recited in claim 36, wherein said sensing device comprises an applied
2 field coil on a cylindrical coilform and sensor coils axially spaced from said field coil on either
side thereof.

41. The apparatus recited in claim 40, wherein said sensor coils are oppositely around
2 in a gradiometer configuration.

42. The apparatus recited in claim 40, wherein said coilform is formed of non-
2 magnetic, non-metallic material.

43. The apparatus recited in claim 36, wherein said deformable material is water.

44. The apparatus recited in claim 36, wherein said deformable material is a gel.

45. An apparatus for noninvasively determining magnetic susceptibility variation in
2 body tissue, the apparatus comprising:

a detector assembly comprising:

4 at least one magnetic sensor and an applied field coil for generating a magnetic
field wherein the applied field coil is designed to create a first zone of a finite magnetic
6 field within a selected region of the body, and a second zone of substantially zero
magnetic field outside the selected region; and

8 said at least one magnetic sensor is positioned within said second zone of
substantially zero magnetic field;

10 said detector assembly is attached to a means for oscillating said detector assembly;
a current signal generating source which connects to the applied field coil;
12 a non-conductive, non-magnetic, substantially rigid barrier;
a flexible membrane sealed to said barrier to form a container therewith, there being a
14 deformable material within and substantially filling said container, said material having a
magnetic susceptibility substantially equivalent to that of the body tissue, said container being
16 shaped and configured to fill in substantially all gaps between said barrier and the patient's body;
and
18 means for processing signals from said at least one magnetic sensor of observed magnetic
susceptibility variation in the body.

46. The apparatus recited in claim 45, wherein said magnetic sensor attaches to a
2 central region relative to said applied field coil.

47. The apparatus recited in claim 45, wherein said applied field coil comprises two
2 parallel flat coils and a connecting circuit between said two parallel coils causing current to flow
in identical directions at corresponding locations in said two flat coils, thereby simulating
4 parallel uniform sheets of current.

48. The apparatus recited in claim 45, wherein said excitation field coil comprises at
2 least two concentric coils and a connecting circuit between said at least two concentric coils
causing current to flow in opposite directions, thereby canceling the effects of a magnetic field
4 caused by current flowing through said applied field coil at a central region of said at least two
concentric coils.

49. The apparatus recited in claim 45, wherein said detector assembly is multiple
2 stacked applied field coils.

50. The apparatus recited in claim 45, wherein said at least one magnetic sensor is a
2 magnetoresistive sensor, said sensor forms part of a Wheatstone bridge circuit and further
comprises a means for compensating said magnetic sensor for locking an optimal operational
4 state by applying a compensating electrical current from said compensating means thereby
maintaining sensitivity of the apparatus.

51. The apparatus recited in claim 45, wherein said at least one magnetic sensor is a
2 fluxgate sensor.

52. The apparatus recited in claim 45, wherein said at least one magnetic sensor is a
2 magnetoinductive sensor.

53. The apparatus recited in claim 45, wherein said applied field coil comprises a coil
2 on a cylindrical coilform and said at least one magnetic sensor comprises sensor coils axially
spaced from said field coil on either side thereof on said coilform.

54. The apparatus recited in claim 53, wherein said sensor coils are oppositely around
2 in a gradiometer configuration.

55. The apparatus recited in claim 53, wherein said coilform is formed of non-
2 magnetic, non-metallic material.

56. The apparatus recited in claim 45, wherein said deformable material is water.

57. The apparatus recited in claim 45, wherein said deformable material is a gel.

58. Apparatus to eliminate background tissue response is an instrument for non-
2 invasively measuring magnetic susceptibility variations in the body tissue of a patient to
determine a compositional state in the body, said apparatus comprising:

4 a non-conductive, non-magnetic, substantially rigid barrier; and
a flexible membrane sealed to said barrier to form a container therewith, there being a
6 deformable material within and occupying most of the volume within said container, said
material having a magnetic susceptibility substantially equivalent to that of the body tissue, said
8 container being shaped and configured to fill in substantially all gaps between said barrier and
the patient's body.

59. The apparatus recited in claim 58, wherein said deformable material is water.

60. The apparatus recited in claim 58, wherein said deformable material is a gel.

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